

Observations of Supergiant Fast X-ray Transients with LOFT

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Abstract

Supergiant Fast X-ray transients are a subclass of high mass X-ray binaries displaying a peculiar and still poorly understood extreme variability in the X-ray domain. These sources undergo short sporadic outbursts ($L_X \sim 10^{36}$ - 10^{37} erg s $^{-1}$), lasting few ks at the most, and spend a large fraction of their time in an intermediate luminosity state at about $L_X \sim 10^{33}$ - 10^{34} erg s $^{-1}$. The sporadic and hardly predictable outbursts of supergiant fast X-ray transients were so far best discovered by large field of view (FOV) coded-mask instruments; their lower luminosity states require, instead, higher sensitivity focusing instruments to be studied in sufficient details. In this contribution, we provide a summary of the current knowledge on Supergiant Fast X-ray

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Transients and explore the contribution that the new space mission concept LOFT, the Large Observatory For X-ray Timing, will be able to provide in the field of research of these objects.

Keywords: neutron star, accretion, X-ray binaries, instrumentation

1. Introduction: the Supergiant Fast X-ray Transients

Supergiant Fast X-ray transients (SFXTs) are a subclass of supergiant X-ray binaries (SGXB, e.g., [Sguera et al., 2005](#); [Negueruela et al., 2006](#)) comprising a neutron star (NS) accreting from the wind of its supergiant companion. At odds with the so-called “classical” SGXBs, which show a nearly persistent X-ray luminosity ($\sim 10^{35}\text{--}10^{37}$ erg s $^{-1}$), SFXT sources exhibit only sporadic outbursts reaching $\sim 10^{37}$ erg s $^{-1}$ and lasting from minutes to hours. In-between these outbursts, SFXTs spend long intervals of time in lower luminosity states ($\sim 10^{33}\text{--}10^{34}$ erg s $^{-1}$) during which a less pronounced flaring activity has also been observed ([Bozzo et al., 2010](#); [Sidoli et al., 2010](#); [Bodaghee et al., 2011](#)). These flares occur on time scales similar to that of the brightest outbursts (few thousands seconds), but the peak luminosity reaches $\sim 10^{35}$ erg s $^{-1}$ at the most. The X-ray luminosity of the faintest emission state of SFXTs can be as low as 10^{32} erg s $^{-1}$, i.e. a factor of $\sim 10^5$ lower than the brightest outbursts. To date, around 15 SFXTs have been identified. Five of these have extreme variability (luminosity dynamic range $\sim 10^5$), whereas the others display a more moderate behavior (luminosity dynamic range $\sim 10^3$) and are termed “intermediate SFXTs” (for a recent list see, e.g. [Falanga et al., 2011](#), and references therein).

Except for their peculiar X-ray variability, SFXT sources share many properties with previously known SGXBs. Measured orbital periods in SFXTs range from 3 to 50 days, and are thus similar to those of other SGXBs. The only exception is the SFXT IGR J11215-5952, with an orbital period of 165 days ([Romano et al., 2007, 2009](#)). The relatively high eccentricity inferred in two SFXTs ($\sim 0.3\text{--}0.7$; Zurita-Heras & Chaty 2009, A&A, 493, 1) suggested that some of these systems might be characterized by somewhat more elongated orbits than classical SGXBs, but this conclusion seems not to be applicable to the most extreme SFXTs, which also have short orbital periods (IGR J16479-4514: $P_{orb}=3.32$ days ([Jain et al., 2009](#)); IGR J17544-2619: $P_{orb}=4.92$ days ([Clark et al., 2009](#))). In these cases, only a very reduced eccentricity (if any) can be assumed to avoid that the orbit of the NS gets too close to the surface

of the supergiant companion. Spin periods have been securely measured only in three intermediate SFXTs and in IGR J11215-5952, and the estimated values (~ 100 -1000 s) are compatible with those expected from classical SGXBs (Bodaghee et al., 2012). None of the most extreme SFXTs have shown clear evidence for pulsations: the 4.7 s pulsations detected from IGR J18410-0535 were so far never confirmed (Bozzo et al., 2011) and only a hint of detection was found for possible pulsations at 71 s from IGR J17544-2619 (Drave et al., 2012). In two extreme SFXTs some evidence was found for spin periods as large as 1000-2000 s (Smith et al., 2006).

The similarity between the geometrical and physical properties of the SGXBs and SFXTs makes it difficult to develop a self-consistent scenario to interpret the behaviour of both systems in the X-ray domain.

According to the “extremely clumpy wind model”, the outbursts of SFXTs might be caused by the sporadic accretion of exceptionally dense clumps of material (populating the inhomogeneous wind of the supergiant star) onto the compact object (in’t Zand, 2005; Walter & Zurita-heras, 2007). Early-type stars are indeed characterized by highly structured and variable massive winds which have an inherently clumpy nature (Oskinova et al., 2007). In this case, clumps with densities $\sim 10^4$ - 10^5 higher than the surrounding stellar wind would be required to match the dynamic range of the X-ray luminosity in SFXTs. These clumps are expected to obscure (partially) the X-ray source when passing close to it, and thus in a few cases the measured variations of the local absorption column density during intense SFXT activity episodes were associated to these passages (Rampey et al., 2009; Bozzo et al., 2011). Recent simulations on clumpy wind accretion (Oskinova et al., 2012, ; see in particular Fig.3 in the paper) showed that this mechanism cannot explain the complete behavior of the SFXTs in X-rays. Indeed, beside the large X-ray luminosity variations produced by the accretion of these clumps (every few thousands seconds), the predicted long-term averaged X-ray luminosity for these objects (on orbital time-scales) would be close to that expected for classical SgHXBs and orders of magnitude higher than that measured from the SFXTs (Romano et al., 2011). This is particularly puzzling for the short-orbital period SFXTs, for which also the possibility of having very large eccentric orbit to alleviate the problem seems to be ruled out for geometrical constraints.

At least for the extreme short orbital period systems, other mechanisms might be required to explain their observational properties. Among these, it was proposed that centrifugal and magnetic “gating” mechanisms, due to

the rotation of the NS and the intensity of its magnetic field, can halt (most of) the accretion flow during the orbital motion and reduce the average luminosity (Grebenev & Sunyaev, 2007; Bozzo et al., 2008). In particular, the magnetic gate model can produce a wide dynamic range in X-ray luminosity ($\gtrsim 10^4$) even if accretion is taking place from a mildly inhomogeneous wind (small clumps) at the price of assuming that the NS is endowed with a long spin period (>1000 s) and a very strong magnetic field ($\gtrsim 10^{14}$ G). As only very little is known about the SFXT spin periods and direct evidence of magnetic field in the required range (e.g. cyclotron lines) are difficult to obtain, the phenomenology of the SFXT remains still a matter of debate.

In the following, we show how the instruments on-board the new ESA space mission candidate LOFT, the Large Observatory For X-ray Timing, will be able to contribute to the SFXT science and significantly deepen our understanding of these objects.

2. LOFT, the Large Observatory For X-ray Timing

LOFT (Feroci et al., 2012), the Large Observatory for X-ray Timing, is one of the four M3 space mission concepts selected by the European Space Agency (ESA) on February 2011. It is presently competing for a launch opportunity in 2022-2024. The mission is mainly devoted to the study of timing and spectral properties of X-ray emission in the proximity of black holes and neutron stars, in order to test general relativity in the strong field regime and constrain the neutron star equation of state (Feroci et al., 2011).

The main instrument on-board LOFT, the Large Area Detector (LAD), is a non-imaging collimated experiment with an unprecedented large collecting area for X-ray photons (2-80 keV) reaching ~ 10 m² at 8 keV. This instrument will provide a total of ~ 240000 cts s⁻¹ for a 1 Crab source and achieve a spectral resolution of ~ 260 eV in the energy band 2-30 keV (in the 30-80 keV range only a coarse energy resolution will be available). Single-anode events will be endowed with an even better energy resolution (<200 eV), approaching the performance of CCD-based X-ray telescopes. The time resolution of the LAD is <10 μ s. This large area instrument could be conceived within the envelope of a medium-class size mission thanks to the technology of the large area Silicon drift detectors (SDDs) and the capillary plate collimators (see Feroci et al., 2011, and references therein).

The LOFT payload comprises also a coded mask Wide Field Monitor (WFM; Brandt et al., 2012). The WFM makes use of the same SDDs

developed for the LAD, but with a design optimized for imaging purposes (Campana, 2012). It can achieve a timing ($\sim 10 \mu\text{s}$) and spectral resolution ($\sim 300 \text{ eV}$) similar to that of the LAD, while observing more than 1/3 of the sky at once (the main operating energy range is 2-50 keV; events in the 50-80 keV energy range will be mainly used to better evaluate the LAD background, see Feroci et al., 2012). An on-board intelligence, combined with a VHF transmitter, will be able to recognize and broadcast to the ground a number of bright impulsive events detected by the instrument within a delay of $<30 \text{ s}$ and a positional accuracy of $\sim 1 \text{ arcmin}$ (the so-called LOFT Burst Alert System, LBAS; Brandt et al., 2012). During observations of bright sources with the LAD, and in other cases in which the LAD will be occupying most of the available telemetry, the WFM will be operating with reduced resources, such that data might be available only with limited time ($\sim 300 \text{ s}$) and spectral (16 energy bands) resolution. The main science goal of the WFM is to detect new transient sources going off in the sky and monitor state changes of known celestial objects suitable for pointed observations with the LAD. However, given its unique capabilities, the instrument is able to carry out important scientific investigations by itself (particularly relevant is the case of Gamma-Ray Bursts, X-ray bursts and transient outbursts such as those from SFXTs; Brandt et al., 2012).

A summary of the capabilities of the WFM and the LAD is provided on the mission website¹.

3. LOFT observations of SFXTs

In this section we provide an overview of the potential of LOFT to improve our knowledge on the outburst and lower activity X-ray emission of the SFXT sources.

3.1. Observations of SFXTs in outburst with the LOFT/WFM

As described in Sect. 1, the outbursts of almost all SFXTs have a sporadic nature and are thus best discovered with large FOVs. The unprecedented wide FOV of the LOFT/WFM is thus well suited to catch SFXT outbursts. In Fig. 1, we show the position of all 15 known SFXTs (see Sect. 1) superimposed on the WFM FOV assuming the instrument is pointing toward the Galactic Center (the WFM FOV map is provided by the

¹See <http://www.isdc.unige.ch/loft/index.php/instruments-on-board-loft>.

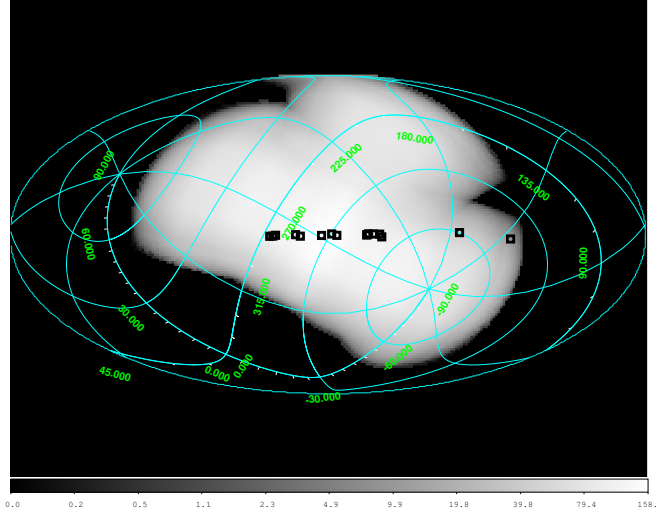


Figure 1: The WFM large FOV is able to catch all the known SFXTs at once while pointing, e.g., toward the Galactic center. We plot for simplicity in grey the WFM FOV as provided by the LOFT WFM team (see text for details) and superimposed the positions of all known 15 SFXTs (see Sect. 1).

LOFT WFM team²). The WFM is able to catch all known SFXTs in a single shot while pointing toward the Galactic Center, thus giving the possibility to observe multiple outbursts from different sources simultaneously. In order to estimate the number of outbursts that can be expected from the known SFXTs during the LOFT life-time, we searched into the Swift (Gehrels et al., 2004) triggers for each source. The BAT (Barthelmy et al., 2005) is scanning the sky regularly in a more uniform way with respect to other similar wide field instruments (e.g., the INTEGRAL/ISGRI; Lebrun et al., 2003; Ubertini et al., 2003). We considered both BAT regular triggers, as disseminated through GCN (independently on whether they were followed by a Swift slew to point with the narrow-field instruments at them or not), and strong on-board detections (those that would trigger the BAT with the current triggering thresholds), as mostly reported in Romano et al. (2009, 2011) and at <http://www.ifc.inaf.it/sfxt/>. In particular, we estimated the

²See <http://www.isdc.unige.ch/loft/index.php/preliminar-response-files-and-simulated-background>.

Table 1: Expected number of outbursts observable from the known SFXT sources with the LOFT/WFM.

Source	Swift/BAT	expected WFM detections	
	(outbursts/yr)	outbursts in 4 yr	outbursts in 5 yr
IGR J08408–4503	$>2^a$	8	10
IGR J11215–5952	2^b	8	10
IGR J16479–4514	5^c	20	25
XTE J1739–302	4^c	16	20
IGR J17544–2619	4^c	16	20
AX J1841.0–0536	2^c	8	10
AX J1845.0–0433	$>1^a$	4	5
IGR J18483–0311	$>1^a$	4	5
IGR J16328–4726	$>0.5^a$	2	2
IGR J16418–4532	$>0.5^a$	2	2

^a: Estimated, lower limit, as number of BAT triggers yr^{-1} . See the reference section of <http://www.ific.inaf.it/sfxt/> for the complete reference list.

^b: This source shows periodic flares at periastron every ~ 165 d (Romano et al., 2007, 2009).

^c: Number of on-board detections per year from Romano et al. (2009, 2011) extrapolated to 4 and 5 years of LOFT mission.

expected number of outbursts from IGR J11215–5952 which shows periodic flares at periastron every ~ 165 d (Romano et al., 2007, 2009) as 2 per year. A summary of our findings is reported in Table 1. As the LOFT mission is being planned to last for 4 yrs plus 1 yr extension (Feroci et al., 2012), about 110 SFXT outbursts can be observed. This number is considered to be a conservative lower limit, as the WFM will have a higher sensitivity with respect to the Swift/BAT, and the much larger FOV is expected to contribute significantly to the discovery of new sources in this class. Note that a number of instrumental effects that will affect the final WFM performances (e.g., vignetting, off-axis angles, ...) are not included yet in the current simulations of SFXT observations with LOFT. These are indeed expected to be clarified only when the instrument properties will be fully consolidated and an advanced imaging simulator will be made available by the WFM team for general usage (Donnarumma et al., 2012).

At odds with previously wide field monitor instruments that observed SFXT outbursts (i.e. Swift/BAT and INTEGRAL/ISGRI), the WFM on-board LOFT will have a significantly lower energy threshold (down to 2 keV),

and will thus be able to catch the “prompt emission” of these events also in an energy range in which a number of spectral features are expected. Particularly interesting are changes in the local absorption column densities, which might be associated to the passage of clumps close to the accreting objects (see Sect. 1). Variations of the power-law spectral index are also expected to provide indications of changes in the accretion flow geometry close to the surface of the NS (Bozzo et al., 2010). In Fig. 2 we show how the LOFT/WFM would be able to see a bright outburst from the SFXT IGR J16479-4519³. We assumed in this case a power-law spectral shape with photon index $\Gamma=0.97$, an absorption column density of $6.5 \times 10^{22} \text{ cm}^{-2}$, and a cut-off energy of 13.5 keV as measured by Romano et al. (2008, 2-10 keV observed flux $5.9 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1}$). The contour plots show the uncertainties on the measured spectral parameters Γ and N_{H} by assuming exposure times of 2 ks and 5 ks. The figure thus confirms that the LOFT/WFM is able to measure spectral parameters of the SFXT outbursts with a reasonably good accuracy and a time resolved spectral analysis can be carried out by using integration times as low as $\lesssim 2$ ks. Measuring spectral variations in a large sample of events can provide crucial information on the triggering mechanisms of such phenomena (Bozzo et al., 2011).

The broad-band high energy resolution spectra that the WFM will provide for the SFXT outbursts can also be used to search for those spectral features that might have gone undetected so far due to: (i) the limited energy resolution and the long integration times required for the currently available wide field instruments (INTEGRAL/ISGRI and Swift/BAT) to achieve the adequate signal-to-noise ratio (S/N), and (ii) the limited energy coverage of present focusing X-ray telescopes (< 10 keV). As a speculative demonstration we show in Fig. 3 a simulation in which we added to the spectrum of a bright outburst from IGR J16479-4514 (Fig. 2) a cyclotron line (GABS in XSPEC) with a centroid energy of 10 keV (we assumed for the depth τ and width σ of the line parameters values typical of accreting NS, i.e. $\tau=2$ and $\sigma=1.5$ keV; see e.g. Ferrigno et al., 2011, and reference therein). The figure shows that the LOFT/WFM is well suited to discover these features with integration times as low as 2 ks. The detection of cyclotron lines at energies $\gtrsim 10$ keV,

³In this paper we use for the WFM and LAD spectral simulations the latest available response and background files of the instruments available on the official LOFT website (LAD response and background files v. 4.0; WFM response files v.2.0): <http://www.isdc.unige.ch/loft>.

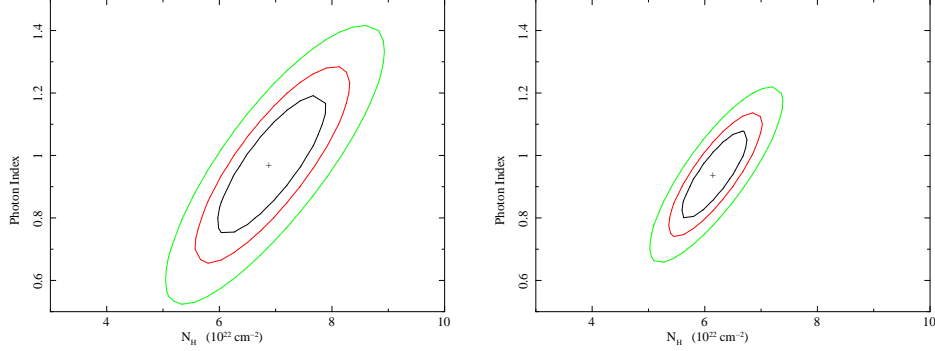


Figure 2: Simulation of the observation of a bright outburst ($2\text{-}10\text{ keV}$ flux of $5.9 \times 10^{-9}\text{ erg cm}^{-2}\text{ s}^{-1}$ not corrected for absorption) from the SFXT IGR J16479-4514 with the LOFT/WFM. We show the 68%, 90% and 99% c.l. contours for the uncertainties on the most relevant spectral parameters, i.e. the power-law photon index, Γ , and absorption column density, N_H (see text for details). Left figure is for an integration time of 2 ks, right figure for 5 ks.

as found in many accreting NSs, gives a direct measurement of the magnetic field strength of the compact object, and might help distinguishing among some of the different models proposed to interpret the SFXT behavior (see Sect. 1). Indeed, a cyclotron line with a centroid energy in the range covered by the instruments on-board LOFT would indeed be indicative of relatively low magnetic fields ($\sim 10^{12}\text{ G}$) compared to those expected in case of magnetars ($> 10^{13}\text{-}10^{14}\text{ G}$). We note that, as the energy of the cyclotron line scales with the strength of the magnetic field (Ferrigno et al., 2011, and references therein), this feature would fall outside the operating energy range of LOFT for a magnetar-like field.

If not ruled-out by the detection of cyclotron lines at energies $\gtrsim 10\text{ keV}$, evidence of magnetars in the SFXTs might still be inferred through alternative methods, as the measurement of the NS spin period and its derivative (see, e.g. Finger et al., 2010). A description of the LOFT capabilities in searching for pulsations in the SFXT X-ray emission is provided in Sect. 3.4.

3.2. Observations of SFXTs in lower activity states with the LOFT/WFM

Apart from the bright outbursts, SFXTs spend a large fraction of their lifetime in lower emission states, with luminosities a factor $10^3\text{-}10^5$ lower than in outburst. A few SFXTs (4) were monitored by Swift for more than two years, and the low emission states could be classified and well characterized in terms

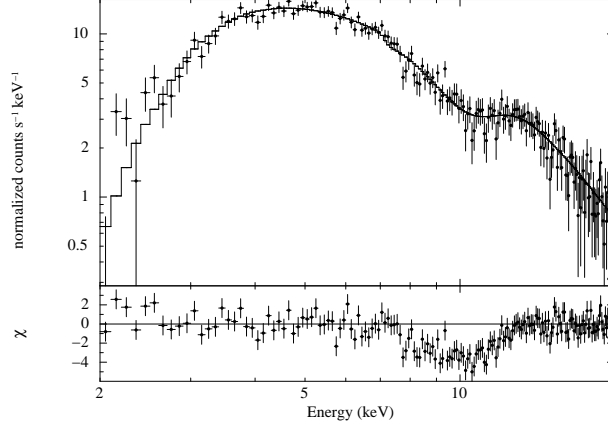


Figure 3: Simulation of the observation of the same outburst in Fig. 2, where a cyclotron absorption line at 10 keV was artificially added (see text for details). The residuals of the model that do not include the line are displayed in the bottom panel. The LOFT/WFM is well suited to discover these features with integration times as low as 2 ks.

of average luminosities and spectral parameters. We refer in the following to the classification presented by Romano et al. (2011, see in particular Table 8 in their paper). For each of the emission states identified for the four objects, we reported in Table 2 the exposure time needed to have a 5σ detection with the LOFT/WFM. The high and medium emission states become accessible to the WFM in relatively short exposure times (a few ks to a few tens of ks). The instrument will thus be able to monitor sources in these states by providing several detections per day (almost all sources can be observed simultaneously during a single pointing, see Fig. 1). This will constitute an unprecedented database of historical flux variations in these systems, that might also help discover orbital periods in poorly known SFXT systems (see, e.g. Zurita-Heras & Chaty, 2009, and reference therein). These measurements are also of crucial importance to understand the accretion mechanism in SFXTs, as they hold the potential to probe directly the accretion environment around compact objects and compare the latter with theoretical estimates of: (i) the distribution of clumps in the wind of supergiant stars, (ii) the structure and evolution of hot star winds.

From Table 2 we note that the lowest emission states of the SFXT are hardly observable by the LOFT/WFM, and require long exposure times.

Table 2: Exposure time needed for 5σ detections of some SFXTs during their different emission states (outside outbursts). The states have been defined according to Table 8 in [Romano et al. \(2011\)](#).

Source Name	WFM exp. time in ks		
	High State	Medium State	Low state
IGR J16479-4514	3.3	15.9	160.3
IGR J1739-302	4.7	209.0	—
IGR J17544-2619	42.3	410.0	—
IGR J18410-0535	12.3	58.6	540.0

Based on the 1 yr sky exposure map⁴ expected at present, we estimated that the WFM will be able to reach a limiting flux of $\simeq 3 \times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ for all the SFXTs (5σ c.l.). For SFXT distances of 3-5 kpc ([Rahoui et al., 2008](#)), this corresponds to a luminosity of $(3-10) \times 10^{32}$ erg s $^{-1}$, i.e. close to the lowest quiescent level displayed by these objects.

3.3. Observations of SFXTs with the LOFT/LAD

As the LAD is a non-imaging pointed instrument with a FOV of ~ 1 deg., observing by chance a sporadic outburst from an SFXT requires too long exposure times. However, there exists at least one source in this class for which we know that outbursts always occur at the periastron passage, and are thus predictable. Indeed, the SFXT IGR J11215-5952 regularly displays outbursts every ~ 165 d, and typically remains in a rather active X-ray phase for about 5 days around the event ([Sidoli et al., 2007](#)). Dedicated observational campaigns with the LAD can be planned to efficiently cover the beginning of the outburst, across the entire event, in order to monitor changes in the spectral parameters (e.g., the absorption column density) and possibly on the spin period (~ 187 s). The latter measurements can reveal the presence and intensity of accretion torques, in turn probing the geometry of the accretion flow around the NS and the properties of the environment from which the accretion takes place (see e.g. [Bildsten et al., 1997](#), and references therein).

In Fig. 4, we show a simulation of a typical outburst from the IGR J11215-5952 (see Fig. 4 and 6 in [Romano et al., 2009](#)) with the LAD. For an exposure

⁴<http://www.isdc.unige.ch/loft/index.php/preliminar-response-files-and-simulated-background>

time of 2.5 ks, comparable to the integration time of some Swift/XRT pointings during the outburst of this source, the LAD is able to collect a total of 20000 counts, leading to a determination of the spectral parameters Γ and N_{H} within a 1-2% accuracy (compared to 30% for Swift/XRT). This demonstrates that, if a similar event is observed with the LAD, significant variations of these spectral parameters (20-30%) can be measured by using integration times as short as few tens of seconds. This will give the unique possibility to study the phenomenology of SFXTs on time scales shorter than the local dynamical times (few hundreds seconds), leading to new discovery windows for these objects so far completely unexplored.

Note that the LAD will also be able to observe these sources not only during outburst, but also during fainter emission states (see Sect. 1). Given the unprecedented large effective area and fine spectral resolution, the LAD is particularly well suited to detect and measure iron lines from the spectra of the SFXT sources in these states. These features can be used to study the physical properties of the accreting environment around compact objects, and in SFXT sources can provide evidence for the presence of massive clumps (see e.g. [Bozzo et al., 2008, 2011](#), and references therein). In Fig. 4, we simulated the spectrum of the SFXT IGR J16479-4514 as was measured by XMM-Newton before the ingress to the eclipse. On that occasion the iron line emerged from the continuum spectrum due to the obscuration of the accreting NS by the supergiant companion. The integration time of the XMM-spectrum was 4 ks (see Fig. 2 in [Bozzo et al., 2008](#)). The LAD is able to detect the line at high significance with an exposure time of 1 ks.

3.4. Spin period measurements in SFXTs with LOFT

The high time resolution and the large collecting area of the WFM and LAD (see Sect. 2) are crucial to reveal pulsations in the X-ray emission of the SFXTs. The detection of relatively long spin periods ($\gtrsim 1000$ s), possibly associated with strong period derivatives, might provide evidence for the presence of magnetars in these sources, and favor the “gating” accretion model (see discussion in 3.1). So far, very little is known about the spin period of NSs in the SFXTs, as the active state in most of these sources last for just a few hours and makes the collection of enough counts to search for significant features in the corresponding power spectra challenging (e.g. [Bozzo et al., 2011](#), and references therein). By assuming the currently envisaged performance of the instruments on-board LOFT (Sect 2), we investigated the exposure time needed to measure a certain spin period with the LAD

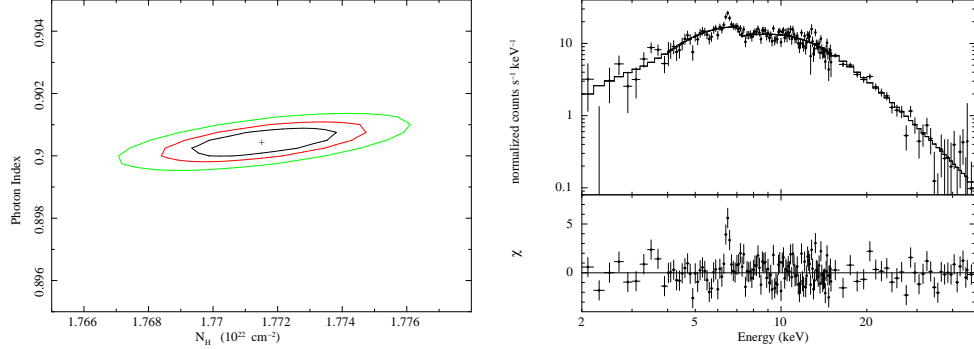


Figure 4: *Left*: Simulation of an outburst from IGR J11215-5952 as observed with the LAD. In this case we reproduced the same spectral parameters measured by Swift/XRT in 2009 during 2.5 ks at the peak of the event (observation “001” in Romano et al., 2009). Here $\Gamma=0.9$, $N_H=1.77\times10^{22}$ cm $^{-2}$, and the luminosity is 5×10^{35} erg s $^{-1}$. In 2.5 ks the LAD is able to collect about 20’000 cts from the source and recover the spectral parameters to within 1-2% accuracy (compared to the 30% achieved by Swift/XRT). *Right*: Simulation of the eclipse ingress of the source IGR J16479-4514. The spectral parameters are the same as measured by XMM-Newton (Bozzo et al., 2008), but the integration time is only 1 ks with the LAD. The iron line at 6.4 keV is clearly detected in the residuals from the fit shown in the bottom panel (the line was not included in the fit).

and the accuracy with which pulsations can be searched with the WFM during an outburst from an SFXT. We assumed a sinusoidal pulse profile and performed Fourier transform searches with 2^{23} - 2^{24} sampled frequencies. Under these assumptions, the pulsed fraction of the smallest detectable signal, PF , is related to the total number of counts available, N_{ph} , by $PF \propto N_{ph}^{-1/2}$. The results of our calculations are summarized in Table 3. We considered three values of the source flux corresponding roughly to a bright outburst (6×10^{-9} erg/cm 2 /s), a fainter flare (6×10^{-10} erg/cm 2 /s), and a low emission state (10^{-12} erg/cm 2 /s) of the SFXT prototype IGR J16479-4514 (see Sect. 3.2).

By using an integration time comparable to the typical duration of an SFXT outburst (i.e. a few ks), the WFM will be able to reveal pulsations in the X-ray emission recorded from the source during the event down to relatively small pulsed fractions (a few %). Similar exposure times with the LAD permit to perform sensitive searches for pulsations also during the low emission states of these sources ($\sim10^{-12}$ erg/cm 2 /s).

Table 3: Detection of pulsations from the X-ray emission of an SFXT in different emission states with the WFM and the LAD on-board LOFT (see also [Romano et al., 2012](#)).

Instrument	Flux ^a (erg/cm ² /s)	Pulsed Fraction (%)
WFM ^b	6×10^{-9}	2.4 (5σ)
	6×10^{-10}	66 (5σ), 56 (3σ)
LAD	6×10^{-9}	0.1 (5 ks, 5σ)
	6×10^{-10}	0.3 (5 ks, 5σ)
	1×10^{-12}	53.4 (10 ks, 3σ)

^a: Flux is in the energy band 2-10 keV.

^b: An exposure of 5 ks is assumed.

4. Conclusions

The SFXTs are characterized by a very unique and peculiar behavior in the X-ray domain, with triggering mechanisms still to be understood. The fast variability of these sources makes any observational campaign challenging and so far only wide field instruments with limited sensitivity and coverage at energies <15 keV were able to efficiently catch a high number of sporadic outbursts from these objects. Spectral features in the lower emission states (outside outbursts), which provide information on the accretion environment, could only be poorly investigated. This is mainly due to the large observational time required for the higher sensitivity focusing instruments to collect a sufficient number of photons and their limited energy coverage (<10 keV).

The instruments on-board LOFT will be able to deepen our understanding of the SFXT sources. A large number of outbursts will be observed during the LOFT life-time by the wide FOV of the WFM, which will provide for these events also coverage of the prompt emission in the soft X-ray domain. Observations with the LAD during outbursts will make it possible to perform time-resolved spectral analysis with integration times lower than the typical accretion dynamical time-scales close to the NS; this will open new discovery windows for the phenomena related to the SFXTs. The very large effective area of this instrument will also permit to detect spectral features in the X-ray emission of these sources that might help unveil the properties of their surrounding accretion environments.

Both the WFM and the LAD will permit to search and measure pulsations in the X-ray emission from the SFXT sources with an unprecedented accuracy

and down to very low pulsed fractions (few %) and pulse periods up to several thousands seconds.

Acknowledgements

EB acknowledges travel support from the Swiss Committee on Space Research (CSR) to attend the COSPAR 2012 meeting, and two anonymous referees for having contributed significantly to improve the manuscript. PR and VM acknowledge financial contribution from the contract ASI-INAF I/004/11/0.

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